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JOVIAN EQUATORIAL H_2 EMISSION FROM 1979–1987

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ABSTRACT

Ninety two IUE observations of the Jovian equatorial region taken by Johns Hopkins University observers between 2 Dec 1978 and 1 Feb 1988 were averaged together by date of observation, resulting in 22 averaged spectra which were fit with a model to determine the amount of H_2 Lyman band emission in the region 1552–1624Å. The data suggest that the H_2 emission may vary with time. Especially suggestive is the marked downward trend of the emission between 1983 and 1987, during which time the strength of the emission in the 1552–1624Å region decreased by about a factor of 10. Uncertainty in the existing data and a gap in the data in 1980 and 1981 preclude a positive identification of a correlation between the brightness of the H_2 emission and the major solar cycle.

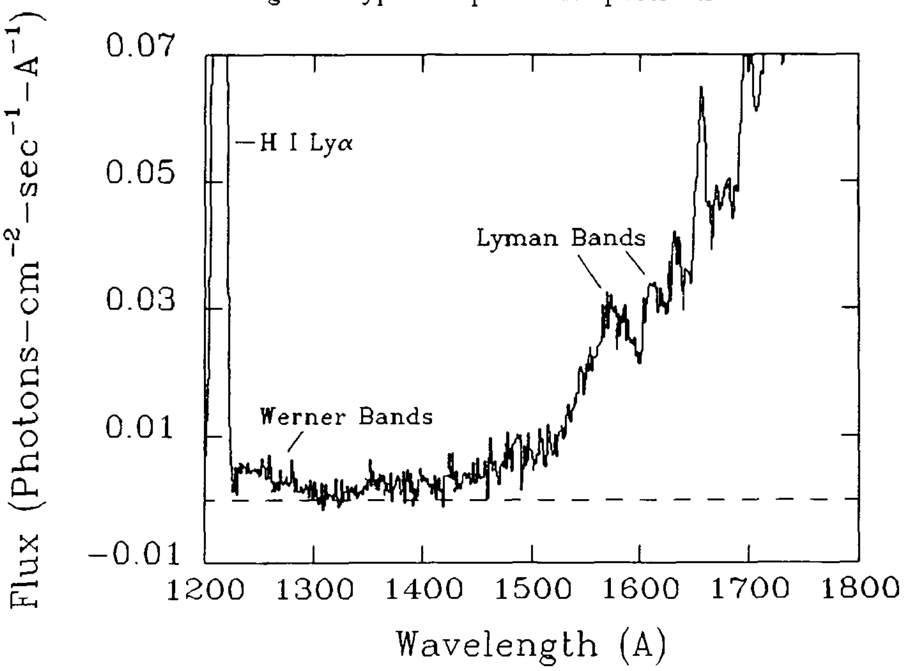
INTRODUCTION

Molecular hydrogen emission from Jupiter's atmosphere was first detected in the Lyman bands of the Rydberg band systems by sounding rocket experiments in the early 1970s (Refs. 1, 2). Positive identification of the Werner bands was not made until the *Voyager 1* flyby (Ref. 3) when two distinct phenomena were also identified: intense emissions confined to the northern and southern auroral ovals and diffuse emission uniformly distributed over the sunlit hemisphere of the planet and not apparently connected with auroral activity (Ref. 4). The same distinct phenomena were subsequently observed by *Voyager 1* on Saturn and Uranus (Refs. 5, 6). The most obvious source for the diffuse UV emissions is photoelectron excitation of H_2, the predominant constituent of the atmospheres of Jupiter, Saturn and Uranus. However, the intensity of the diffuse emissions on all three of these planets is much higher than that predicted by calculations of the solar energy input into the atmosphere via photoelectron excitation of H_2. The discrepancy on Jupiter and Saturn is about a factor of 5 and on Uranus about a factor of 15 (Ref. 7). Although the emission must be triggered by solar photons because it is only seen in the dayside atmosphere, the energy for the emission process must be produced locally in the atmosphere (Ref. 8). Because the origin of the diffuse emissions is unknown, yet is common to the three outer planets visited by *Voyager 1* to date, Broadfoot *et al.* (Ref. 6) coined a new term, "electroglow", to describe this unexplained phenomenon.

Several different explanations for the electroglow have been put forward (Refs. 7, 8, 9, 10). Since all theories depend on some process which is triggered by solar energy input, the realtionship of electroglow to the major solar cycle is "a matter of vital interest" (Ref. 9). Reanalysis of early observations of Jovian atmospheric emissions by Shemansky and Judge (Ref. 11) showed relatively little variation in the disk-averaged (that is, auroral plus diffuse) H_2 band emission compared to a large variation in the H I Lyα emission brightness between 1972 and 1979. Nine years (1979–1987) of virtually continuous observations of the Jovian atmospheric emissions with the *International Ultraviolct Explorer* (IUE) satellite spanning solar cycle 21 (with maximum in ~1980 and minimum in ~1986) are also available for such an analysis. Skinner *et al.* (Ref. 12) used this database to show that the (non-auroral) Jovian H I Lyα emission brightness varied with the long-term solar Lyα output, decreasing by a factor of ~2 over the time period covered by the observations. However, as can be seen from Fig. 1, the

H_2 band emission signal is very weak and not easily separated from the background, in sharp contrast to the very strong Lyα emission, which is easily measured. the Lyα emission (the so-called Lyα "bulge"), tentatively confirming the *Voyager 1* detection of no significant enhancement in bulge to non-bulge emission for H_2.

Fig. 1. Typical equatorial spectrum



In the short wavelength region covered by the IUE (~1150–1900Å) the H_2 Werner band emission, which is detected from ~1240–1280A, is weaker than the detectable Lyman band emission (~1550–1620A) and therefore subject to large uncertainty due to background subtraction problems. Unfortunately, although the Lyman band signal is stronger, it lies in a region of the spectrum where the solar continuum and the albedo of the planet rise sharply (see Fig. 2), making an accurate subtraction of the background level difficult. A previous analysis by Coplin (Ref. 13) used a least squares method in which a model spectrum composed of the 1552–1624Å region of a bright Jovian north pole auroral spectrum and an *assumed* linear background

$$Model(\lambda) = a_o + a_1\,\lambda + a_2 * auroral\ flux(\lambda)$$

was fit to the corresponding region of 21 equatorial spectra to determine the intensity of the H_2 Lyman band emission (a_2) in the 1552–1624Å region. The results of the Coplin analysis were consistent with a constant level of emission of ~1 kR over the period 1982–1986. A very rough division of the spectra into two 180° longitude bins showed no enhancement in the H_2 Lyman band emission corresponding to that observed in

One of the most serious uncertainties in the Coplin analysis was the assumption of a linear background over the region of the Lyman band emission. In addition, observations made between 1978 and 1981 (and observations subsequent to the Coplin study, 1987–present) were not included in the analysis. Presented below is a more sophisticated determination of the background which has been substituted for the linear one used in the Coplin model. The H_2 emission from the expanded data set was then evaluated using the same least squares analysis as that of Coplin to determine the variation with time (if any) of the H_2 Lyman band emission in the 1552–1624Å region.

For our purposes the observed flux in an IUE spectrum of Jupiter can be thought of as simply

$$\begin{aligned} Observed\ flux(\lambda) &= Background(\lambda) + H_2\ emission(\lambda) \\ &= \omega\left(\frac{A(\lambda)\,F_\odot(\lambda)}{\pi\,R_J^2} + H_2\ emission(\lambda)\right) \end{aligned}$$

where

$$\begin{aligned} \omega &= \text{IUE slit size} \\ R_J &= \text{sun-Jupiter distance in AU (5.203 AU)} \\ A(\lambda) &= \text{the albedo of Jupiter} \\ F_\odot(\lambda) &= \text{the solar flux measured at the earth} \end{aligned}$$

Note that the shape of the background with wavelength is determined by the solar flux incident on Jupiter's atmosphere and the amount of the incident flux which is "reflected" by the atmosphere (the albedo). The albedo is determined by the major constituents of Jupiter's atmosphere, namely H_2 and He, which scatter the incident radiation, and hydrocarbons such as acetylene (C_2H_2) and ethane (C_2H_6), which absorb the incident solar flux. We use a theoretical model of the Jovian albedo by Gladstone and Yung (Ref. 14—model #2) which is based on a homogeneous atmosphere with constant mixing ratios of $H_2 = 0.89$, $He = 0.1$, $C_2H_2 = 1.1 \times 10^{-7}$, $C_2H_6 = 6.5 \times 10^{-6}$, C_4H_2 (diacetylene) $= 2.6 \times 10^{-10}$, and C_2H_4 (ethylene) $= 4.9 \times 10^{-10}$. This model is known to match a typical equatorial IUE spectrum well over the wavelength range 1500–1750A. The background is computed at 1A intervals and then smoothed to IUE resolution (~10 A). The model albedo, solar flux (scaled) and the resulting "background" used in determining the H_2 emission are shown in Fig. 2. Note that the small scale features (~10A) come mainly from the solar spectrum, whereas the general rise in the background over the region of the Lyman band emission is determined by the albedo.

With the improved background determination, the model used in the least squares fit to the data becomes

$$Model(\lambda) = a_o + Bck(\lambda) + a_2 * auroral\,flux(\lambda)$$

The 1552–1624A region of a typical spectrum and the fit to the data are shown in Fig. 3.

Fig. 3. Fit to data in the 1552–1624A region.

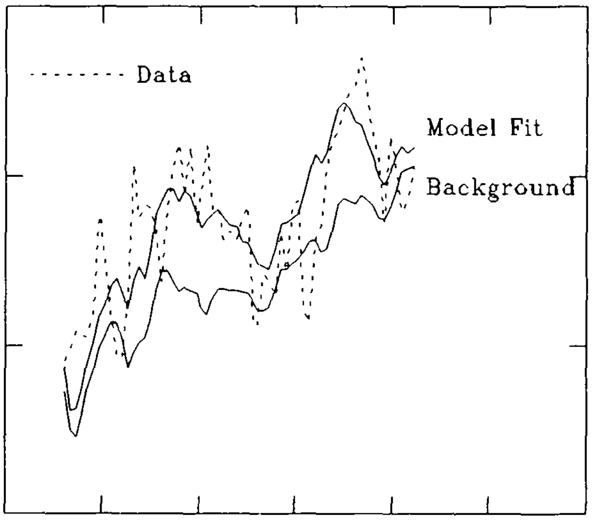
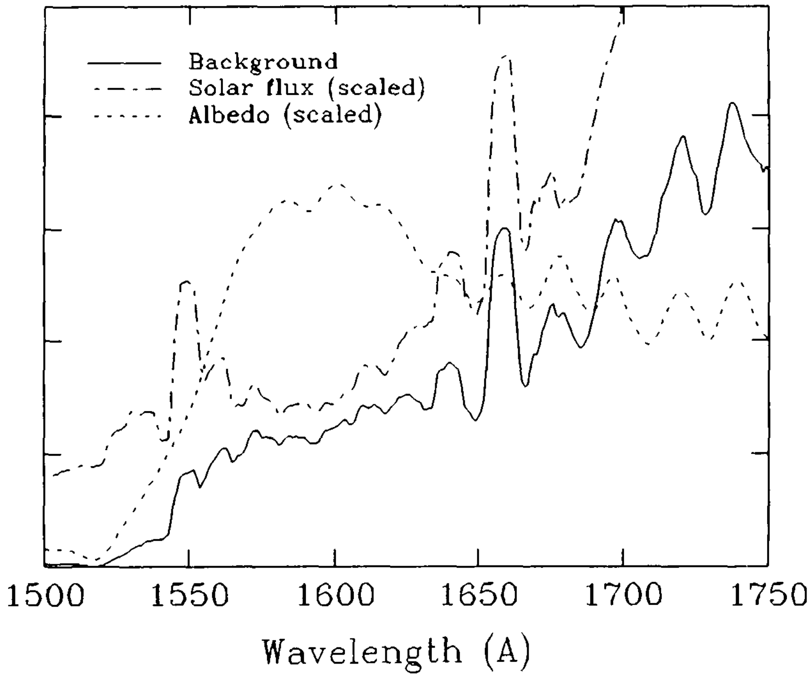


Fig. 2. Model albedo, solar flux and resulting background



RESULTS

Ninety two IUE observations of the Jovain equatorial region by Johns Hopkins University observers taken between 2 Dec 1978 and 1 Feb 1988 were averaged together by date of observation, resulting in 22 averaged spectra, which were then fit with the model described above to determine the amount of H_2 Lyman band emission in the region 1552–1624Å. The results of this analysis are shown in Fig . 4.

Although still preliminary, the data suggest that the H_2 emission in this region may vary with time. Especially suggestive is the marked downward trend of the emission between 1983, when the H_2 1552-1624Å Lyman band brightness was ~1 kR, and mid-1987, when it was ~0.1 kR. The low emission in 1978/79 and late 1981, 82, and 83, and the lack of data in 1980 and 81 preclude an unambiguous identification of a correlation between the H_2 emission and the major solar cycle. However, note that the late 1982 and 83 data points also have the largest uncertainties. The addition of data from observers other than those at Johns Hopkins, as well as analysis of the H_2 Werner bands continues and may allow more definitive conclusions to be drawn in the near future.

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Fig. 4.